Excel for Two-Sided Matching: A Users' Manual (excerpt)*

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1 Introduction

1.1 Recommended Operating Environment

This is a users' manual for *Excel for Two-Sided Matching* to solve two-sided matching problems with a computer. As of January 2025, *Excel for Two-Sided Matching* version 3.2 (two-sided-matching.xlsm) is available at a github repository. Below is the URL.

> https://github.com/shuya-abe/excel-for-two-sided-matching

In the repository, click on the green button "Code" to open a drop-down list. Then, choose "Download Zip." This is the simplest way to download the file.

The screen-shots in this manual were taken in the environment shown in Table 1.

Table 1: Environment of screen-shots

OS	Windows 10 Enterprise
Excel	Microsoft Office 2016 Excel
CPU	Intel(R) Core(TM) i7-3770K CPU @ 3.50GHz 3.90GHz
Memory	8 GB
Disk	1 TB

Excel for Two-Sided Matching runs on computers that can use Excel VBA (Visual Basic for Applications). The recommended environment is listed in Table 2.

Table 2: Recommended environment

OS	Windows 7–CMac OS X 10.8–
Excel	Microsoft Office 2013–CMicrosoft Office for Mac 2016
CPU	no requirement if Excel works
Memory	at least 2GB
Disk	no in particular

1.2 Some Notes

(1) *Excel for Two-Sided Matching* consists of 5 Excel sheets (man, group, conf, result, analyze) and 1 VBA program. If assistance is needed for reading and writing VBA codes, refer to an appropriate textbook.

(2) Two-sided matching is an assignment problem. Matching workers and divisions in a company is an example, and the following information is used.

    (a) Workers and divisions in a company: each worker has a preference over the divisions to which he or she is to be assigned, and each division conducts evaluations of the workers. The preferences and evaluations are represented by ranking without ties.

    (b) Quota: the maximal number of workers that can be accepted by each division, i.e., capacity.

(3) Users need to input numerical values in **Arabic numerals (not double-byte characters) without multiple numbers and without missing values** for initial settings, workers' preferences, divisions' evaluations, and quotas of each division.

(4) *Excel for Two-Sided Matching* uses a program written in Visual Basic. Thus, unlike editing a regular Excel sheet, users cannot restore states by pressing the "backspace" key or pressing the "Z" key while holding down the "Ctrl" key. It is possible to return the Excel file to the intended state before editing by closing the Excel file without saving the current state.

(5) The computation results are overwritten each time the program is run. Thus, users need to make a copy of the computation results in another file, when they wish to accumulate and save those results.

2 Using *Excel for Two-Sided Matching*

2.1 Getting Started

Initially, set the numbers of workers and divisions in the VBA window. See Fig.1. By default, the number of workers is set as 20 and the number of divisions is set as 5.
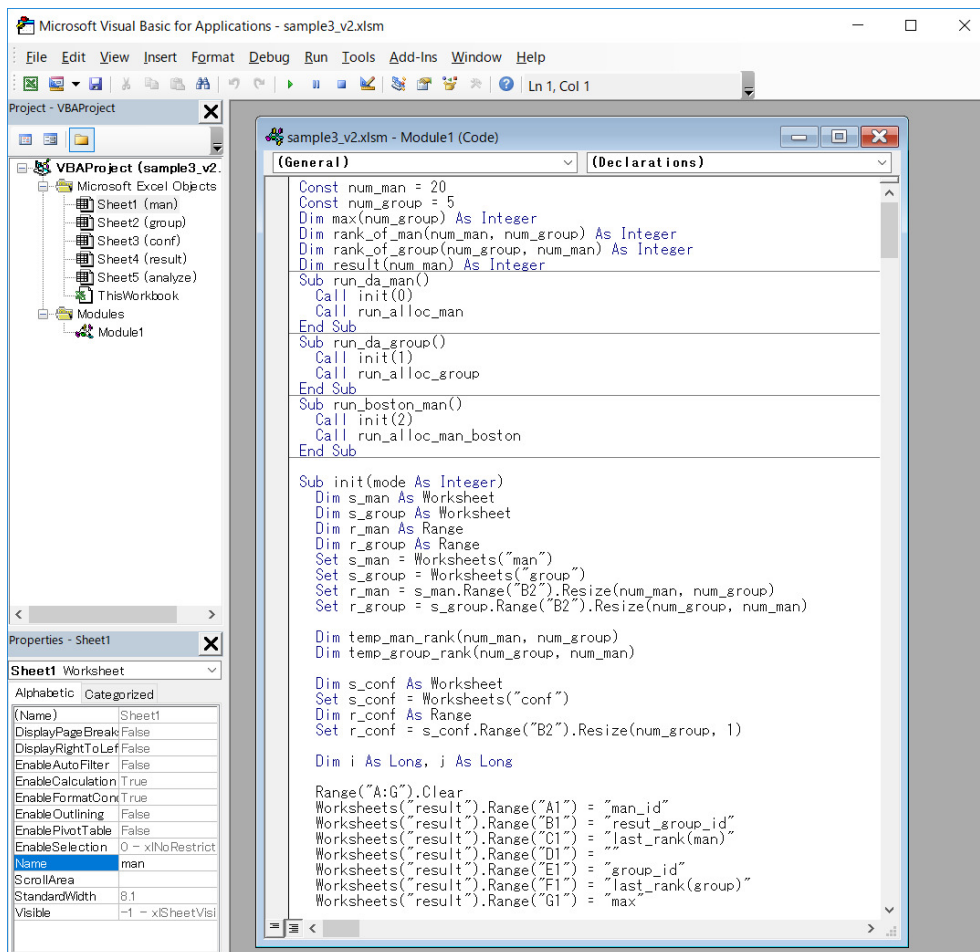
Figure 1: Visual Basic window

1. Click on the **Visual Basic** button on the **Developer** ribbon.

2. Find **VBAProject (sample3_v2.xlsm)** by **Project** explorer.

3. Open **Module 1** in the **Standard Module** that is under **VBAProject (sample3_v2.xlsm)**.

4. Change the numbers in `Const num_man` to set the number of workers, and change the numbers in `Const num_group` to set the numbers of divisions. These are the first two lines in **Module 1**.

5. Save to the same file and close the Visual Basic window.

2.2 Running the Program

1. Complete the initial setting for the numbers of workers and divisions in the Visual Basic window.

2. Input numerical data on workers' preferences, divisions' evaluation, and quotas in the (1) man sheet, (2) group sheet, and (3) conf sheet, respectively.

3. Open the (4) result sheet.

4. Choose one button out of three in the result sheet.

   - Click on the da (man) button for computing a matching with the worker-proposing DA algorithm.
   - Click on the da (group) button for computing a matching with the division-proposing DA algorithm.
   - Click on the boston (man) button for computing a matching with the worker-proposing DA algorithm.

5. View computation results in the result sheet.

6. Click on the eval button for examining efficiency of a matching shown in the result sheet.

7. Open the (5) analyze sheet and view the examination result in the analyze sheet.

(1) man sheet

Input workers' preferences over divisions in Arabic numerals. See Fig.2, where 20 workers all report their preferences over 5 divisions.

Rows in column A (man_id): Input worker IDs in ascending order **without multiple numbers and without missing values**.

Rows in column B and thereafter (g_rank): Each row is used for a worker. Input the division ID worker i prefers at the jth rank in the cell corresponding to row (man_id) i and column (g_rank) j. (In Fig.2, the second-best division (g_rank2) for a worker with ID=5 (man_id=5) is a division with ID=4.) The value put in cell 6C is thus 4.

randomize **button:** Use this button to generate the workers' preferences randomly.

Figure 2: man sheet

(2) group sheet

Input divisions' evaluations for workers in Arabic numerals. See Fig.3, where 5 divisions report their evaluations for 20 workers (although the 17th ranked worker and thereafter cannot be seen in the screen-shot).

Figure 3: group sheet

Rows in column A (group_id): Input division IDs in ascending order **without multiple numbers and without missing values**.

Rows in column B and thereafter (m_rank): Each row is used for a division. Input the worker ID division i evaluates at the jth rank in the cell corresponding to row (group_id) i and column (man_rank) j. (In Fig.3, the fourth-best worker (man_rank4) for a division with ID=3 (group_id=3) is a worker with ID=7.) The value put in cell 4E is thus 7.

randomize **button:** Use this button to generate the workers' preferences randomly.

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(3) conf sheet

Input quotas of divisions in Arabic numerals. See Fig.4, where 5 divisions report 20 openings in total.

Figure 4: conf sheet

Rows in column A (group_id): Input division IDs in ascending order **without multiple numbers and without missing values**.

Rows in column B (max): Each row is used for a division. Input the quota of division i in the cell corresponding to "max" in row (group_id). **The total sum of all quotas should coincide with the total number of workers**. In Fig.4, the quota of a division with ID=1 is 6. The value put in cell 2B is thus 6.

(4) result sheet

The computation results are shown in the result sheet. The buttons in this sheet are used to run each computation. See Fig.5, which shows a matching of 20 workers to 5 divisions by rankings according to the workers' preferences and the divisions' evaluations.

Figure 5: result sheet

Rows in column A (man_id): Worker IDs are shown in ascending order.

Rows in column B (result_group_id): Each division matching each worker is shown with the ID.

Rows in column C (last_rank (man)): The rank of the division that matches a worker in his or her preference is shown for each worker. In Fig.5, worker 14 is matched with division 1, which is the 1st rank of his or her preference. The value put in cell 15C is thus 1.

Rows in column E (group_id): Division IDs are shown in ascending order.

Rows in column F (last_rank (group)): The lowest rank of worker among workers matched with a division according to the division's evaluation is given. As shown in the middle of Fig.5, division 3 with quota 4 is matched with the worker who is 16th rank in the evaluation of the division. In division 3, no worker is lower ranked in the evaluation. The value put in cell 4F is thus 16.

Row in column G (max): The quotas put in conf sheet are shown.

(**Caveat**) When the workers' preferences have missing values, an error message appears if worker-proposing algorithms are used, whereas the division-proposing DA algorithms may generate a matching. In the latter case, **it should be an error message if last_rank (man)=0.** The same thing applies to the worker-proposing algorithms when the divisions' evaluations have missing values.

da (man)**button:** Press when worker-proposing DA algorithm is used.

da (group) **button:** Press when division-proposing DA algorithm is used.

boston (man) **button:** Press when worker-proposing Boston mechanism is used.

randomize man **button:** The same function button that appears in the man sheet.

randomize group **button:** The same function button that appears in the group sheet.

eval **button:** Press when the efficiency of a matching shown in the result sheet is examined. The examination result is shown in another sheet (the analyze sheet).

(5) analyze sheet

Consider a situation where a pair of workers exchange their divisions assigned in a matching. If both workers are better off and both divisions are better off by that exchange, then the matching is not (Pareto) efficient. When you press eval button in the result sheet, *Excel for Two-Sided Matching* starts searching for those pairs examining every pair of workers. (It is not necessarily true that a matching is Pareto efficient, even when there is no pair of workers who are both better off and whose divisions are both better off by any exchange of their divisions assigned in the matching.) The examination result is shown in the analyze sheet.

Figure 6: analyze sheet

The analyze sheet shown in Fig.6 lists all pairs of workers who are both better off or whose divisions are both better off by exchange of their divisions assigned in a matching. The numbers colored in yellow indicate the increase in ranking of divisions reassigned to workers by that exchange, while the numbers colored in light blue indicate the increase in ranking of reassigned workers. If there are numbers colored in light green in the analyze sheet, then they indicate that the matching shown in the result sheet is not (Pareto) efficient. The observations of colored numbers are counted and shown in the upper-right part of the sheet.

For instance, In line 22 of Fig.6, workers 5 and 18 who are assigned to divisions 4 and 5, respectively, in a matching are both better off by 1 in ranking of divisions for both workers by exchange of their divisions, which

is indicated by numbers colored in yellow. In the same matching, workers 5 and 16 who are assigned to divisions 4 and 3, respectively, as is seen in line 21. By exchange of their divisions, worker 5 is worse off and worker 16 are better off, but both divisions are better off by 10 and 5, respectively, which is indicated by numbers colored in light blue.

(**A Tips**) You can enter the data of actual assignment in the result sheet. Given workers' preferences over divisions, divisions' evaluations for workers, and the quotas in the man sheet, the group sheet, and the conf sheet, respectively, press eval button, without pressing da (man) button, da (group) button, and boston (man) button. Then, the efficiency of the actual assignment can be tested in the way described above.

In the Boston mechanism, divisions that reach capacity in a certain round are often removed from candidates to which workers can be assigned in the next round. In this case, the divisions are also removed from the workers' preferences over divisions. However, this treatment implies that some workers skip the review of their kth preferred division which they would have received if there was a vacancy, and in effect proceed to the next round to be reviewed for their $k + 1$th preferred division. This point has often been criticized as unfair. In this software, in order to clearly contrast with the DA mechanism as well, divisions that reach capacity are not removed from the candidates for assignment and workers' preferences, and the rounds in which workers are reviewed are aligned for all workers.

3   Troubleshooting

3.1   Developer Ribbon Does Not Appear

In the default, Microsoft Office Excel does not show the **Developer** ribbon. Complete the following procedure (in the case of Microsoft Office Excel 2016).

1. Click on the **File** ribbon.

2. Click on the **Option** ribbon.

3. Click on the **Customize Ribbons** in **Excel Options** window.

4. Confirm whether **Main Tab** appears in the **Customize Ribbons** field (Fig.7), and then look for **Developer** in the list of ribbons in **Main Tab**. Check the check box for **Developer**

5. Click on the **OK** button.

6. Close the **Excel's Option** window, and then the **Developer** button appears. If the button does not, then open the Excel file again.
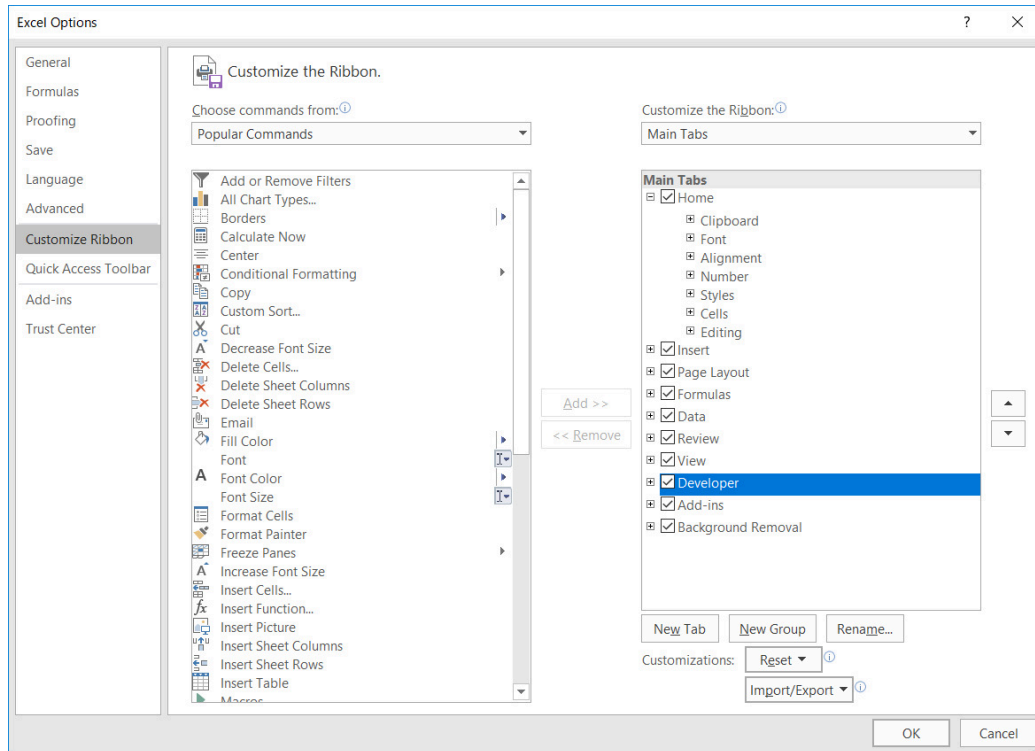

Figure 7: Screen-shot of Excel Options

3.2 Error Messages Appear

Confirm the following points, when error messages appear after pressing the buttons to run the program.

- Did you input data in Arabic numerals with single-byte characters in the VBA window, man sheet, group sheet, and conf sheet?

- Do the numbers of workers and divisions initially set in the VBA window coincide with those put in man sheet and group sheet?

- Does the number of workers initially set in the VBA window coincide with the total sum of all quotas put in conf sheet?

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3.3 No Error Message but Incorrect Matching

Confirm the following points, when error messages appear but the software does not generate a correct matching after pressing the buttons to run the program.

- Did you open your Excel file in Protected View (Fig.8)? In that case, click on the **To Enable Editing** (or **Enable Content**) button to end Protected View.

- Does the total of all quotas coincide with the total number of workers?

- Are there any multiple numbers or missing values in man sheet, group sheet, or conf sheet?
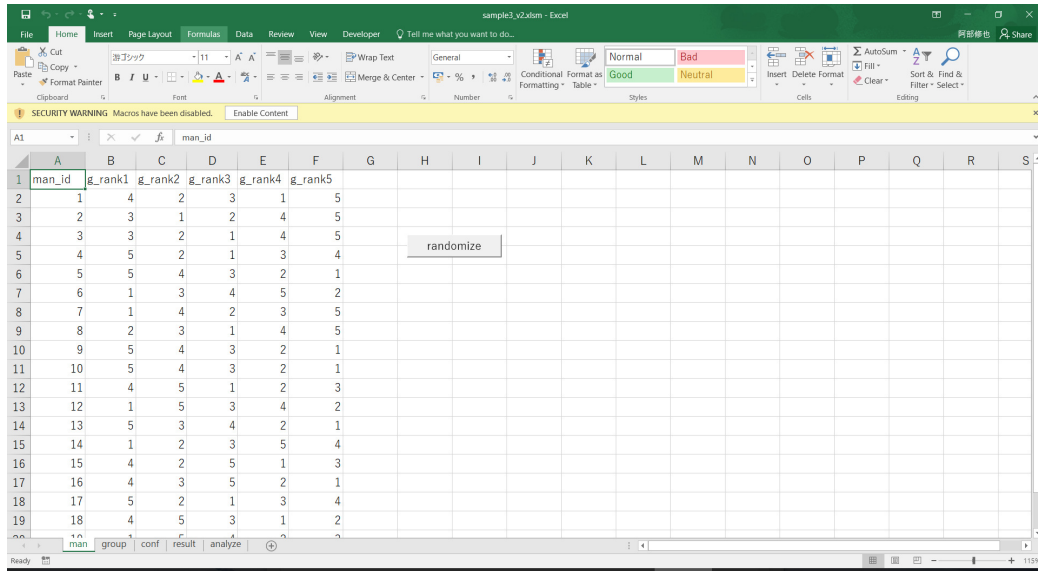

Figure 8: Screen-shot of Protected View

Caveat: Note that *Excel for Two-Sided Matching* will display a run-time error message and basically generate no assignment, if there are missing values in preferences or evaluations.[1] Make complete lists of rankings (preferences and evaluations) in using *Excel for Two-Sided Matching*.

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[1] A matching may be generated if there are missing values on the side of receiving applications, e.g., divisions' evaluations of workers when the worker-proposing DA algorithm is used.

The codes of this software were not written for the consecutive execution. If you use the software listed below in such a way, the codes may refer to numerical values remaining in the cache on your PCs and generate incorrect matchings. In order to surely avoid this event, please clear your cache or close your Excel file for every execution.